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Imidacloprid Reduces *Lygus lineolaris* Damage to White Pine Seedlings

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Introduction

Lygus bugs are serious pests of numerous plant species worldwide, including alfalfa, beans, strawberries, peaches, and tomatoes. These piercing-sucking insects feed on meristematic tissue and developing flowers of host plants (Strong 1969). An enzyme secreted by the bug breaks down plant tissues, resulting in growth malformations and bud and flower mortality. Plant tissue is also destroyed by direct mechanical damage during the feeding process (Kyoto 1992b).

In the early 1980s, lygus bugs, particularly *Lygus lineolaris* Palisot de Beauvois and *L. hesperus* Knight, were identified as pests of seedlings of many conifer species (Shrimpton 1985, South 1986, Schowalter 1987, Holopainen 1989). The insects damage seedlings by feeding on succulent new growth and buds, especially in the first year of growth. Pines are a preferred host relative to other conifer species (Nauen 1995). In Ontario, lygus bug damage occurs mainly in jack pine (*Pinus banksiana* Lamb) and white pine (*P. strobus* L.) container and bareroot crops, although black spruce (*Picea mariana* Mill. B.S.P.) and white spruce (*P. glauca* (Moench) Voss) seedlings are also affected (Greifenhagen et al. 1991, 1992). Typical symptoms of lygus bug damage include the development of weak multiple leaders, terminal shoot distortion, and thick, short, twisted needles (Sutherland et al. 1989) (Figure 1). Multiple-leadered seedlings usually have reduced height growth, which can influence initial growth rate after

Figure 1. Lygus bug damage in a 1-year-old white pine bareroot crop in Ontario.

outplanting, especially on sites with dense competing vegetation (Paterson and Maki 1994, Duryea 1984, Kyoto 1992a). More importantly, affected seedlings are often culled at the nursery because they do not meet shipping standards (Overhulser et al 1987, Gross 1983, Kyoto 1992b). In Ontario, excessive multiple leadering has been observed in seedling crops since 1957, however the lygus bug was not identified as a causal agent until the 1980's (Gross 1983; Sandy Smith, pers. comm.). Damage levels ranging from 35 to 65% have been recorded in Ontario (Greifenhagen et al. 1991, Gross 1983).

Lygus bugs are commonly controlled with repeated contact insecticide applications during the seedlings' active growing phase (Overhulser et al. 1987, Bryan 1989, Sutherland et al. 1989). These pesticide applications can be costly, increase the risk of worker exposure to harmful chemicals, and increase unproductive time because of post-application entry restrictions in greenhouses.

Imidacloprid is a chloronicotynal insecticide that effectively controls sucking insects such as aphids and whiteflies (Mullins 1993, Palumbo et al. 1996). Activity of this systemic insecticide can last up to 12 weeks (Mullins 1993) and effective rates are relatively low, decreasing the required applications, as well as worker exposure and pest control costs. Imidacloprid does not move readily in soil (Mullins 1993) minimizing potential leaching and groundwater contamination risk. Imidacloprid has a different mode of action than many conventional insecticides (Nauen 1995) and may be a valuable tool for controlling insects that are resistant to other pesticides. Use of this insecticide to reduce lygus bug damage to white pine seedlings was investigated because of its systemic nature, long residual activity, and low recommended application rates.

Materials and Methods

Imidacloprid is a systemic insecticide that is readily absorbed by plant root systems. In this study, it was incorporated into the planting mix in granular form.

White pine seeds (Ontario geographic seed source 42-24-0-00) were stratified at 2°C for 90 days prior to sowing. Imidacloprid (Merit® 0.5% granular, Miles Incorporated Specialty Products, Kansas City, Missouri, USA) was thoroughly mixed into enough planting medium (1:1 peat:vermiculite) to fill 20

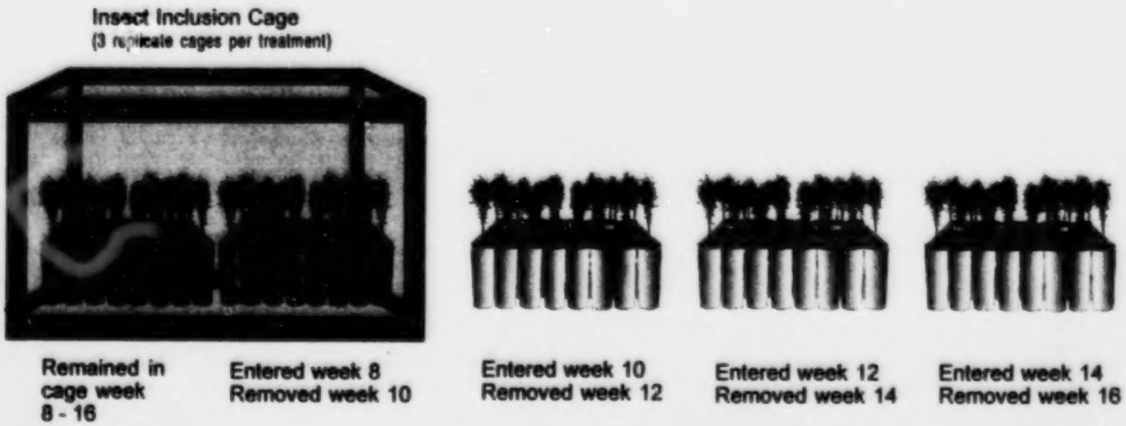


Figure 2. Insect inclusion cage. Multipot trays remained in the cage for 2-week intervals. One tray remained in each cage for the entire 8-week period.

Multipot 67 trays at rates of: 1) 0 g a.i. (active ingredient) per m^3 (control), 2) 0.625 g a.i. per m^3, 3) 1.25 g a.i. per m^3, and 4) 2.5 g a.i. per m^3. These application rates were based on a preliminary test in which bean plants amended with various doses of imidacloprid were exposed to lygus bugs. White pine seeds were sown into the trays in April 1996. Seedlings were grown in the greenhouse under conditions that simulated an operational growing regime: 26°C day temperature, 18°C night temperature, and an 18-hour day.

Three nylon mesh insect inclusion cages per treatment were placed in the greenhouse in a randomized block design. Eight weeks after sowing, 2 Multipot trays were placed into each cage. Five laboratory-reared lygus bugs (*L. lineolaris*) were released into each cage on a weekly basis. After 2 weeks, a tray was removed from each cage and replaced with a new tray of treated seedlings (Figure 2). This bi-weekly introduction of previously unexposed seedlings was repeated 3 times, to determine which physiological stage during the seedlings' first year of growth is most susceptible to lygus bug damage. One of the containers in each cage remained exposed to feeding for the duration of the trial to observe cumulative lygus bug damage over the growing season.

Although the majority of the lygus bugs died within 2 weeks of being released into the inclusion cages, some remained alive longer. Lygus bug pressure was not kept constant at 5 bugs per cage throughout the experiment — it fluctuated over time and among cages.

Seedlings were assessed for persistent feeding damage 5 weeks after being removed from the cages. Forty seedlings per tray were selected, omitting those along the edges of the trays, and rated as having: 1) no shoot damage, 2) multiple leader, or 3) terminal shoot distortion.

The seedlings remained in the greenhouse over the fall and winter. Temperatures were gradually lowered to 5°C under natural day length. In May 1997, the seedlings were placed outdoors under 50% shade. Long-term effects of lygus bug feeding damage were evaluated by assessing 40 seedlings per tray for shoot damage in mid-July once terminal shoot elongation had ceased. Seedlings were rated as having a: 1) single leader, 2) multiple leader, or 3) multiple leader with a taller, dominant leader evident (Figure 3). The height of each seedling was also recorded.

Leader condition was analyzed using CATMOD (categorical modeling) of SAS® (SAS® Institute Inc., Cary, NC, USA). The effect of the various treatments on seedling height was tested using a GLM (General Linear Model) of SAS®, treating leader condition and date of exposure as categorical variables and dose as a quantitative variable.

Leader condition 5 weeks after exposure was compared to leader condition 1 year after exposure. It was assumed that a multiple-leadered seedling in 1996 was more likely to develop a

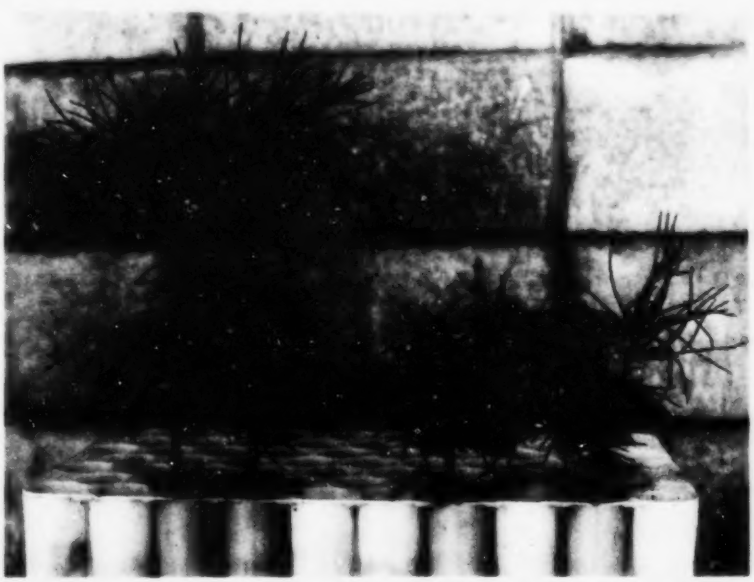


Figure 3. Seedlings 1 year after exposure to lygus bugs for 8 weeks (right) compared to non-exposed seedlings (left).

single dominant shoot by 1997 than a distorted, or *cabbage-headed* seedling, therefore the following leader conditions were compared:

$$\text{Single}_{1996} = \text{Single}_{1997}$$

$$\text{Multiple}_{1996} = \text{New Dominant}_{1997}$$

$$\text{Distorted}_{1996} = \text{Multiple}_{1997}$$

Results

The levels of lygus bug exposure in the experiment caused significant damage to white pine seedlings (Figure 3). Only 17% of the untreated seedlings exposed to feeding throughout the entire experiment had a single leader at the end of the second growing season; the remainder were either multiple leadered (55%) or had developed a new dominant leader (27%) (Figure 4).

Insecticide rate, exposure date, and their interaction were both significant (a=0.05) in 1997. Rate had a strong, curvilinear effect on leader condition for the 8- and 12-week exposure dates, but only a minor, linear effect for the 10- and 14-week exposure dates (Figure 4).

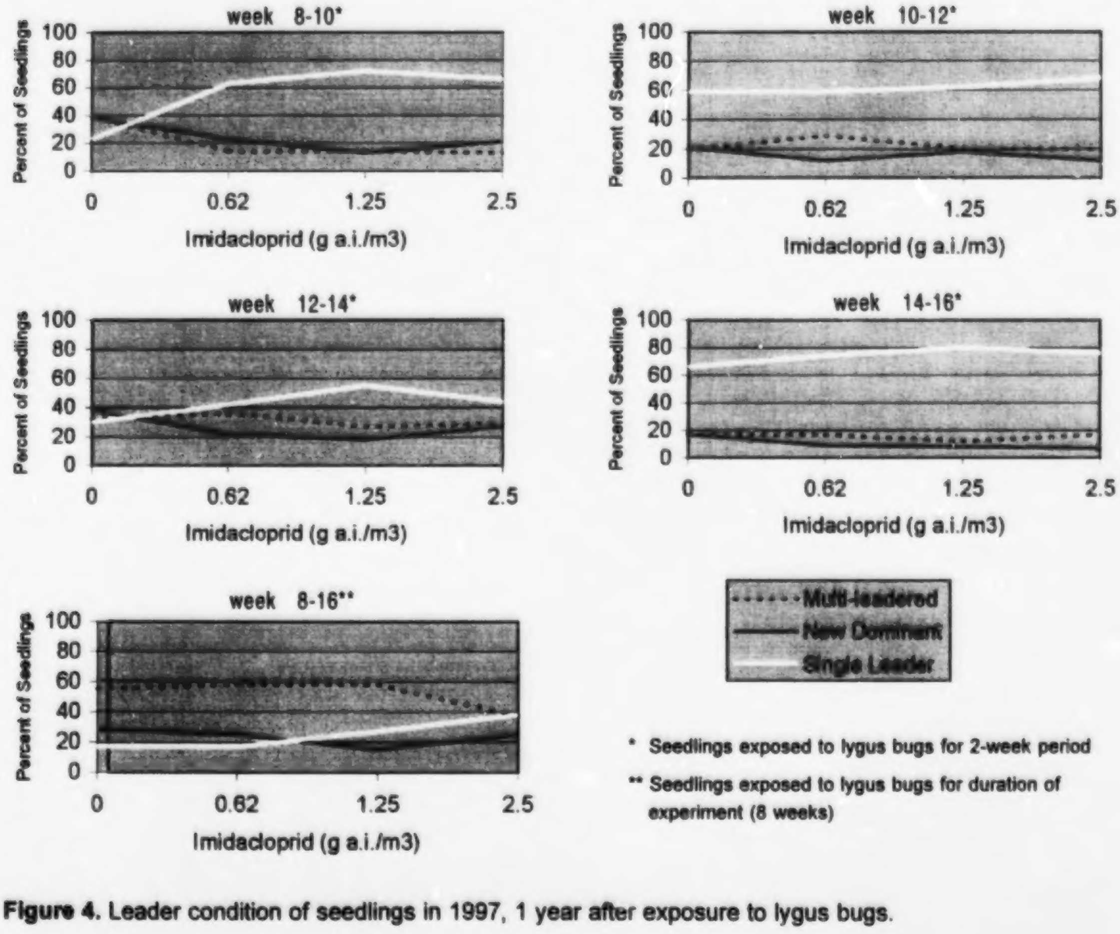
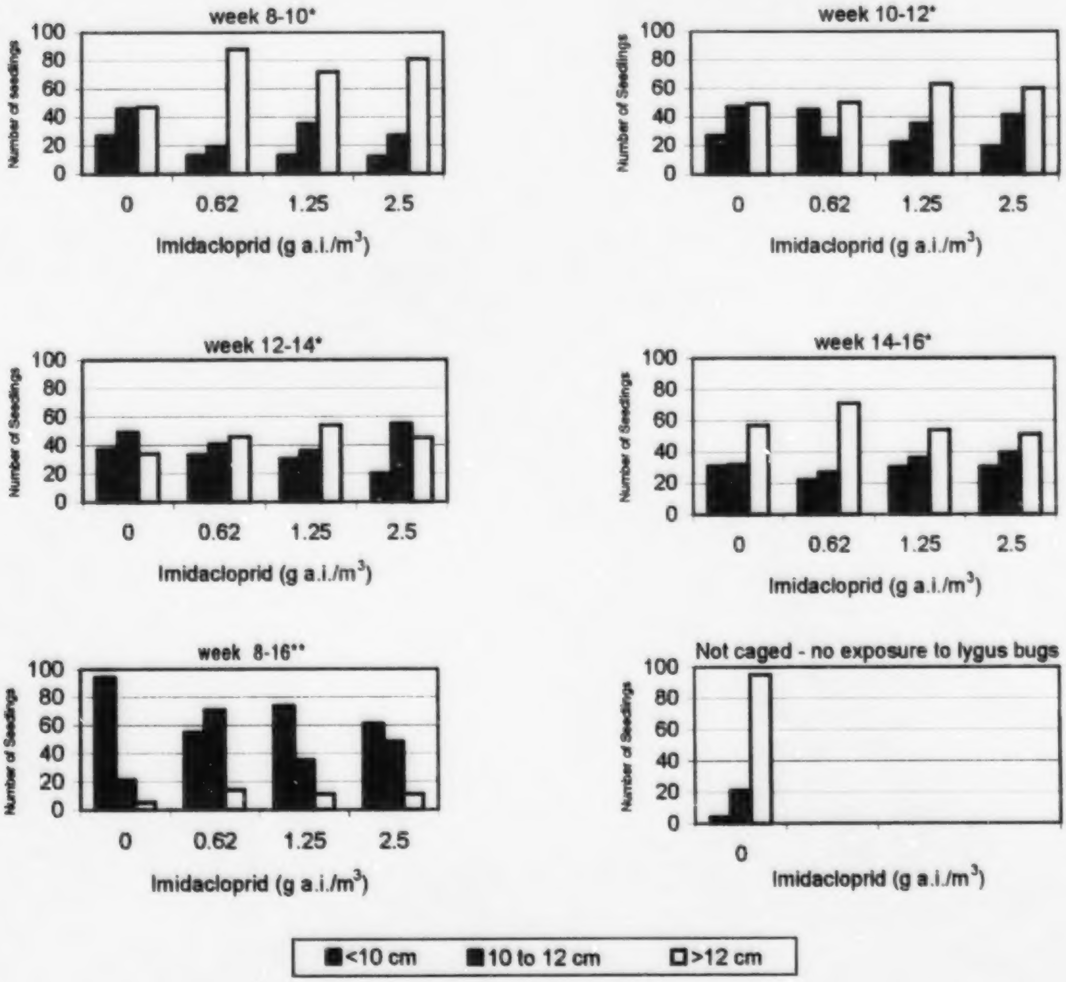


Figure 4. Leader condition of seedlings in 1997, 1 year after exposure to lygus bugs.

When leader condition from both the first and second growing season were modelled, a high correlation was observed between the number of seedlings with each leader condition by treatment (r = 0.79, a < 0.001). However, there were significant interactions between the treatments and year of response, as a number of the multiple-leadered seedlings had developed a new, dominant leader in the second growing season. Leader condition in 1996 was a good predictor of 1997 leader condition in all cases except for the lower doses at the 10-week exposure.

Leader condition had a significant effect on seedling height. At the end of the second growing season, the single-stemmed seedlings were generally taller than the seedlings with a new dominant leader, which in turn were taller than the multiple-stemmed seedlings. Seedlings exposed to lygus bugs throughout the experiment were generally shorter than all other treatments, regardless of leader condition (Figure 5). Insecticide rate did not appear to affect the height of the seedlings except through its effects on leader condition.



* Seedlings exposed to lygus bugs for 2-week period

** Seedlings exposed to lygus bugs for duration of experiment (8 weeks)

Figure 5. Number of seedlings in each of 3 height classes, 1 year after exposure to lygus bugs.

Discussion

Imidacloprid significantly reduced seedling damage caused by lygus bug feeding. This effect was greatest for the first exposure period, when seedlings were 8- to 10-weeks old. In the soil amended with 1.25 g a.i. per m^3, 72% of the seedlings had single leaders (Figure 4) and 72% were greater than 12 cm in height (Figure 5) compared to 23% and 47%, respectively, of the seedlings grown in untreated soil.

Using beans to gauge application rates for white pine was probably not the ideal approach because of differences such as plant growth habit, age, and pot size. For control of numerous insect pests on ornamentals, rates as high as 180 g a.i. per m^3 growing media are listed on imidacloprid product labels. Thus, higher rates may decrease lygus feeding damage on white pine even further than levels reported here.

Reduced protection for the later exposure dates (i.e., weeks 10 to 12 and 12 to 14), and for the seedlings that remained exposed for the entire 8 weeks, indicates that the treatment was not as effective for 10- to 14-week-old seedlings. Higher rates than those tested here may extend protection, although the residual effect of imidacloprid is reported to last only 8 to 10 weeks in poinsettias, impatiens, and chrysanthemums (Lindquist 1994).

Seedlings appear most susceptible to lygus bug feeding during the exponential growth phase, which can last until they are 11- to 13-weeks old (Dave Trotter, pers. comm.). In this trial, seedlings appeared less susceptible to lygus bug feeding by the last exposure date (week 14 to 16) as evidenced by the high proportion of untreated seedlings that remained single-leadered (Figure 4). Because the imidacloprid treatment was only effective for 10 weeks, a second control action, such as the application of a contact insecticide, or a topical application of imidacloprid, may be necessary to achieve adequate control until seedlings are 14 weeks old, or have completed their exponential growth phase.

Conclusions and Recommendations

Lygus bug feeding causes terminal shoot distortion, stunting, and multiple leadering of pine seedlings. Although multiple leadering is usually a temporary phase (Gross 1985, Kyoto 1992b), affected seedlings may be at a disadvantage during initial establishment after outplanting because of reduced height growth. The effects of lygus bug feeding have an even greater impact at the nursery; affected seedlings are often culled because they do not meet shipping standards (Overhulser et al. 1987, Sutherland et al. 1989). Incorporation of imidacloprid into planting media can be an effective, relatively safe tool for managing lygus bugs in conifer seedling crops. Eight-week-old white pine seedlings grown in imidacloprid-amended media sustained significantly less lygus bug damage than those grown in non-amended media. The following recommendations may increase the effectiveness of the treatment:

1) Higher rates of imidacloprid than those tested in this trial may increase the effectiveness and/or length of crop protection. Further testing is required before the most effective dosage is determined.

2) A second, topical application of imidacloprid or a contact insecticide registered for lygus control applied at 10 weeks may extend crop protection until seedlings have completed the exponential growth phase.

3) Applying imidacloprid to seeds prior to planting is another effective application method for crops such as cereals, rice, cotton, and peanut (Mullins 1993). Treating conifer seed could be examined as a method to further reduce cost and worker exposure.

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